Pavement Design for Low Volume Roads

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Types of Low Volume Roads?

Agricultural Access

County Roads

Rural Streets

Got Dust?

Gravel or BST Roads

Photos Courtesy: Washington County, ODOT, and Vestas
Low Volume Road Materials

- Hot Mix Asphalt
- Gravel
- Bituminous Surface Treatment
Low Volume Roads—Failure

Photo Courtesy: Vestas
Low Volume Roads—Failure

Photo Courtesy: Vestas
Low Volume Roads—Failures
Flexible Pavement Design

Flexible Pavement System

Progressively stronger layers

- Wearing Surface—HMA, BST
- Base Course (CBR 50-100)
- Subbase (Optional)
- Frost Protection (Optional)
- Subgrade

Source: Federal Aviation Administration
Must also guard against potential failure in base layers.
Layered Elastic Design—Flexible

Approximate Line of Wheel-Load Distribution

Area of Tire Contact

Wheel Load

Horizontal Strain and Stress at the bottom of the asphalt

Vertical Subgrade Strain

Subgrade Support

Subgrade

Subbase

Base Course

Wearing Surface

Source: Federal Aviation Administration
Flexible Pavement Layer Parameters - LED vs CBR

<table>
<thead>
<tr>
<th>Layer</th>
<th>Elastic Modulus (E)</th>
<th>Poisson’s Ratio (μ)</th>
<th>Thickness (h)</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>E_s, μ_s, h</td>
<td></td>
<td></td>
<td>Not Defined</td>
</tr>
<tr>
<td>Base</td>
<td>E_b, μ_b, h_b</td>
<td></td>
<td></td>
<td>CBR</td>
</tr>
<tr>
<td>Subbase</td>
<td>E_sb, μ_sb, h_sb</td>
<td></td>
<td></td>
<td>CBR</td>
</tr>
<tr>
<td>Subgrade</td>
<td>E_sg, μ_sg, h_sg</td>
<td></td>
<td></td>
<td>CBR</td>
</tr>
</tbody>
</table>

E = Elastic Modulus
h = thickness
μ = Poisson’s Ratio

CBR = California Bearing Ratio

Source: Federal Aviation Administration
Flexible Pavement Design Process

- Climate
- Subgrade
- Traffic

Design

Pavement Section

(AASHTO, AI)
Start with a Field Investigation

- Augering / Shallow Exploration
- Boring/SPT
- Coring
- DCP
Soil Investigations and Evaluation

- Unified Soil Classification System (USCS)
  - ASTM 2487
Deflection Testing
Seasonal Variation

![Graph showing seasonal variation of Resilience Modulus, $M_r$, for Dorland Road - CH 5/6]
16th Street ESAL Calculations

- Use 20-year Design Life
- AADT = 945 vehicles per day
  - School Buses = 10
  - Delivery Trucks = 4
  - Garbage Trucks = 2
  - Tractor/Semi-trailers = 1
- Traffic Growth Rate = 2% annually
Single Unit (2-axle) Truck

\[ 10,000 \text{ lb} \times 0.09 \text{ ESAL} + 10,000 \text{ lb} \times 0.09 \text{ ESAL} = 20,000 \text{ lb} \times 0.18 \text{ ESALs} \]
Single Unit (3-axle) Truck

18,000 lb 1.00 ESAL + 42,000 lb 2.51 ESAL = 60,000 lb 3.51 ESALs
Tractor Semi-Trailer (5-axle)

\[
\begin{align*}
12,000 \text{ lb} & \quad 34,000 \text{ lb} & \quad 34,000 \text{ lb} \\
0.19 \text{ ESAL} & \quad 1.10 \text{ ESAL} & \quad 1.10 \text{ ESAL} \\
\end{align*}
\]

\[= \quad 80,000 \text{ lb} \quad 2.39 \text{ ESALs}\]
## 16th Street ESAL Calcs

<table>
<thead>
<tr>
<th>Class</th>
<th>Vehicle Type</th>
<th>Day</th>
<th>Year</th>
<th>20Y* (k)</th>
<th>Factor</th>
<th>20Y* ESALs</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Autos</td>
<td>503</td>
<td>183,595</td>
<td>3,672</td>
<td>0.00012</td>
<td>440</td>
</tr>
<tr>
<td>III</td>
<td>Pickups</td>
<td>425</td>
<td>155,125</td>
<td>3,103</td>
<td>0.008</td>
<td>24,824</td>
</tr>
<tr>
<td>IV</td>
<td>School Buses</td>
<td>10</td>
<td>1,950</td>
<td>39</td>
<td>1.0</td>
<td>39,000</td>
</tr>
<tr>
<td>V</td>
<td>Delivery Truck</td>
<td>4</td>
<td>1,460</td>
<td>29</td>
<td>0.18</td>
<td>5,220</td>
</tr>
<tr>
<td>VI</td>
<td>Garbage Truck</td>
<td>2</td>
<td>730</td>
<td>15</td>
<td>3.51</td>
<td>52,650</td>
</tr>
<tr>
<td>IX</td>
<td>18-Wheelers</td>
<td>1</td>
<td>250</td>
<td>6.1</td>
<td>2.39</td>
<td>14,159</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>945</td>
<td></td>
<td></td>
<td></td>
<td><strong>136,293</strong></td>
</tr>
</tbody>
</table>
### Environmental Conditions
(for more information, see MS-1, Chapter III)

<table>
<thead>
<tr>
<th>Mean Annual Air Temperature (MAAT)</th>
<th>Frost Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 45°F</td>
<td>Yes</td>
</tr>
<tr>
<td>60°F</td>
<td>Possible</td>
</tr>
<tr>
<td>≥ 75°F</td>
<td>No</td>
</tr>
</tbody>
</table>

**Note:**
Mean Annual Air Temperature (MAAT) was used to characterize the environmental conditions applicable to the continental United States. For detailed information on the development of the MAAT regions, see Asphalt Institute Research Report RR 82-2 “Research and Development of The Asphalt Institute’s Thickness Design Manual (MS-1) Ninth Edition.”
Asphalt Institute SW-1

**Traffic**

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Percent of Traffic</th>
<th>Truck Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Unit Trucks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Axle, 4-Tire</td>
<td>25</td>
<td>0.01</td>
</tr>
<tr>
<td>2-Axle, 6-Tire</td>
<td>18</td>
<td>0.3</td>
</tr>
<tr>
<td>3-Axle or More</td>
<td>7</td>
<td>0.86</td>
</tr>
<tr>
<td>Multiple Unit Trucks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Axle or Fewer</td>
<td>7</td>
<td>0.64</td>
</tr>
<tr>
<td>5-Axle</td>
<td>38</td>
<td>1.36</td>
</tr>
<tr>
<td>6-Axle or More</td>
<td>5</td>
<td>1.63</td>
</tr>
</tbody>
</table>

**Design Period (years):** 20

**Annual Growth Rate (%):** 4

**Classification:** Rural

**Calculated Equivalent Single Axle Load (ESAL):**
- Initial Year ESAL: 83,198
- Design Period ESAL: 2,477,636
Asphalt Institute SW-1

Type of Strength Measure
- CBR

Resilient Modulus Calculation

Design ESAL: 2,477,836

Design Strength Percentile:
- Select Manually
- Value: 50

CBR Correlation Factor, f
- $M_f = f \times \text{CBR}$ for $750 \leq \text{psi} < 3000$
- Value: 1350 psi

Average $M_f$: 29160 psi
Standard Deviation: 6231 psi

Design $M_f$: 29160 psi
Asphalt Institute SW-1
# Pavement Design Detail Report

**SW-1 Thickness Design Software version 1.0**

## Project Information
- **Project Name:** US 195 Harper to Ironsides
- **Description:** Example Problem—See SW-1 User's Guide Chapter 8
- **Pavement Use:** General Roadway
- **Problem Type:** New Pavement Design

## Design Input Summary
- **Climate:** 45°F
- **Design Traffic (ESAL):** 2,477,636
- **Subgrade Mv (psf):** 29,160

## Design Traffic Details
- **Design Life (years):** 20
- **Design Lane Factor:** 0.5
- **Initial Average Annual Daily Traffic (AADT):** 1500
- **Truck Volume, as a percentage of AADT:** 40%
- **Annual Compound Growth Rate (%):** 4
- **Type of usage:** Rural
- **Truck Classification:** Urban, 1% Trucks, 1% Trucks
- **TRUCK (2-AXLE, 4-TIRE):** 25, 0.01
- **TRUCK (2-AXLE, 6-TIRE):** 18, 0.30
Results – CBR

The graph shows the results of a study on CBR (California Bearing Ratio) with respect to saturation. The x-axis represents different core holes labeled with numerical ranges and place names such as Moreland, Dorland, Solberger, Wilkesboro, Reiling, Chalmers, Riedweg, and Dober. The y-axis indicates the saturated CBR values ranging from 0 to 8.

- Green circles represent 'No Distress'.
- Yellow squares represent 'Cracking'.
- Red triangles represent 'Rutting & Cracking'.

Each core hole is plotted with a corresponding CBR value based on its condition of distress.
Results – Base Thickness

- Green circle: No Distress
- Yellow square: Cracking
- Red triangle: Rutting & Cracking
- Black line: 6” Min. Base Depth
Results – Base Thickness

![Graph showing base thickness results with various core holes and symbols indicating rutting levels.](image-url)
Results – % Design Thickness

- Rutting < 1/4”
- Rutting ≥ 1/4”

Existing Base Thickness as % Design Base Thickness

Core Hole


Moreland Dorland Solberger Wilkesboro Reiling Chalmers Riedweg Dober
Resources

AASHTO Guide for Design of Pavement Structures

SW-1
Asphalt Pavement
Thickness Design Software
for Highways, Airports, Heavy Wheel Loads and Other Applications

Version 1.0.5
Developed by the Asphalt Institute and IIT Corporation

Disclaimer: All reasonable care has been taken in the development of this program; however, the Asphalt Institute accepts no responsibility for the consequences of any inaccuracy which it may contain or its suitability or utility for use in any specific set of circumstances. Always use sound engineering judgement.
Pavement Design for Low Volume Roads

Thank You!

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